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SUSITNA-WATANA HYDRO

PART A - APPENDIX A: TRIBUTARY GEOLOGIC BARRIERS

PART A - APPENDIX B: MIDDLE RIVER TRIBUTARY DELTA SURVEYS OUTSIDE OF FOCUS AREAS

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries (9.12)

Part A - Appendix A
Tributary Geologic Barriers

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

June 2014

1. BARRIER FIELD NOTES: UNNAMED TRIBUTARY 189.7, BARRIER A

The potential barrier site was located at the upstream extent of a very high gradient reach of boulder dominated cascades (Figure A1). At the time of survey, flow conditions appeared to be very low, making it difficult to discern the true bottom of the barrier. The surveyed site appeared to be only slightly steeper than the immediate reach downstream, but both the surveyed site and downstream reach appeared to be a barrier to upstream migration.

The site was classified as a fixed seasonal boulder cascade and is likely a fixed permanent barrier. The average barrier height was 8.9 m (29 ft), and the average horizontal length was 10.9 m (36 ft) with an average channel gradient of 83 percent. Low flow conditions, large bed material, and the significant grade did not provide for a clean swim route up the cascade. Resting areas at the upstream and downstream ends of the barrier appeared minimal in the current flow conditions, and no downstream jump pool existed.

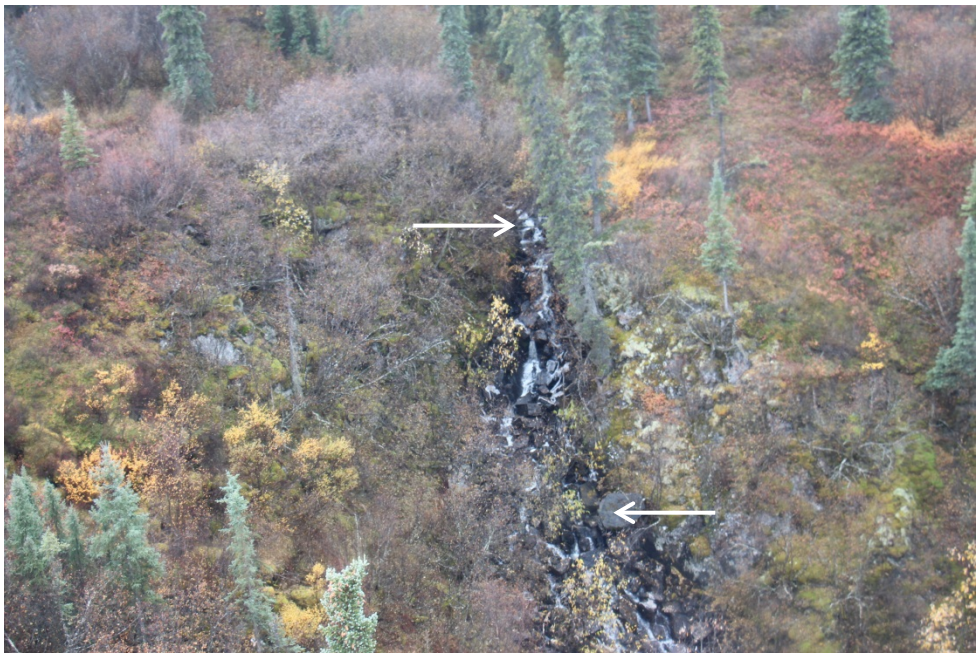

Figure A1. Barrier A in Unnamed Tributary 189.7. Fixed seasonal boulder cascade, 29 ft in height and horizontal length of 36 ft with an average channel gradient of 82 percent.

2. BARRIER FIELD NOTES: UNNAMED TRIBUTARY 197.7, BARRIER A

The potential barrier site was located at the upstream extent of a very high gradient reach of boulder dominated cascades (Figure A2). Flows appeared to moderate to low, and the stream bed was dominated by large boulders and exposed bedrock. Flows entered the cascade and made a 90 degree right turn towards the bottom, and a very minimal pool was located at the bottom.

The site was classified as a permanent fixed boulder cascade. The average barrier height was 13.8 ft (4.2 m), and the average horizontal length was 32 ft (9.8 m), resulting in an average channel gradient of 43 percent. Lower flow conditions, large bed material, and the significant grade did not provide for a clean swim route up the cascade. The barrier's height and length appeared to preclude leaping as a means of passage. Resting areas at the upstream and downstream ends of the barrier were minimal under the observed flow conditions with no downstream jump pool.

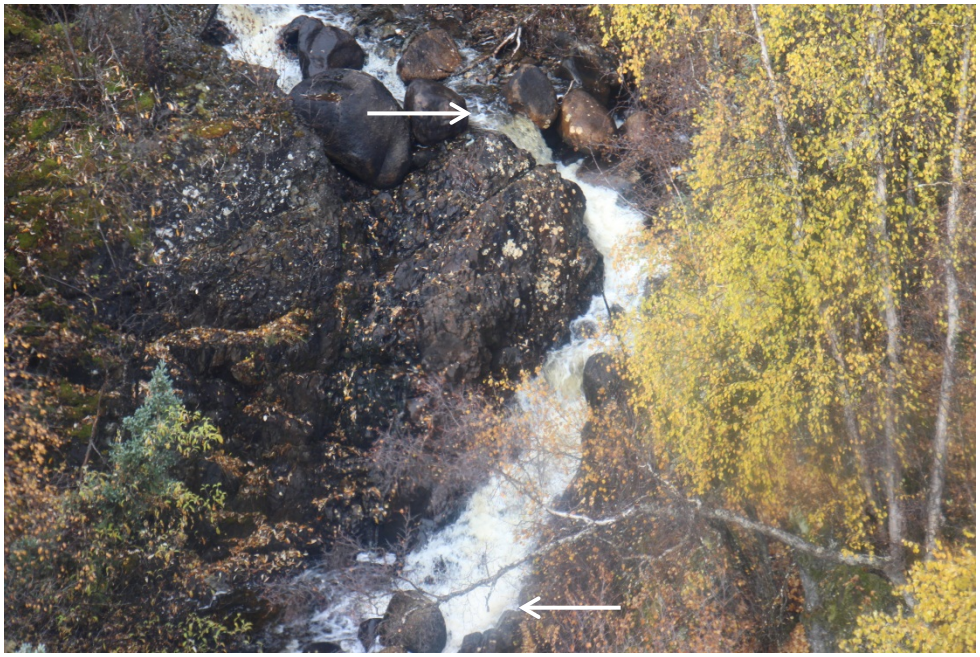

Figure A2. Barrier A in Unnamed Tributary 197.7. Fixed seasonal boulder cascade, 13.8 ft in height with a horizontal length of 32 ft and an average channel gradient of 43 percent.

3. BARRIER FIELD NOTES: UNNAMED TRIBUTARY 204.3, BARRIER A

The potential barrier site was located amid a moderate to high gradient reach of stream dominated by boulder cascades (Figure A3). The site was classified as a fixed permanent single falls. The stream turbulence made it difficult to ascertain the bed material upstream and downstream of the feature, but the falls themselves were formed by an exposed bedrock sill.

As a single fall, and due to its location, only the height of the barrier was assessed. The average barrier height of 10.8 ft (3.3 m), including the measurement error (±1ft), is within the range of Chinook maximum leaping abilities as described by the US Forest Service (2001) but exceeds their leaping abilities as described by Powers and Orsborn (1984) and Reiser and Peacock (1985). A sizeable plunge pool was observed. While no depth could be determined, the pool had sufficient depth to dissipate most turbulence resulting from the plunge. The landing area above the feature appeared to be located in a short, high gradient reach with a small but turbulent resting eddy immediately below another smaller waterfall.

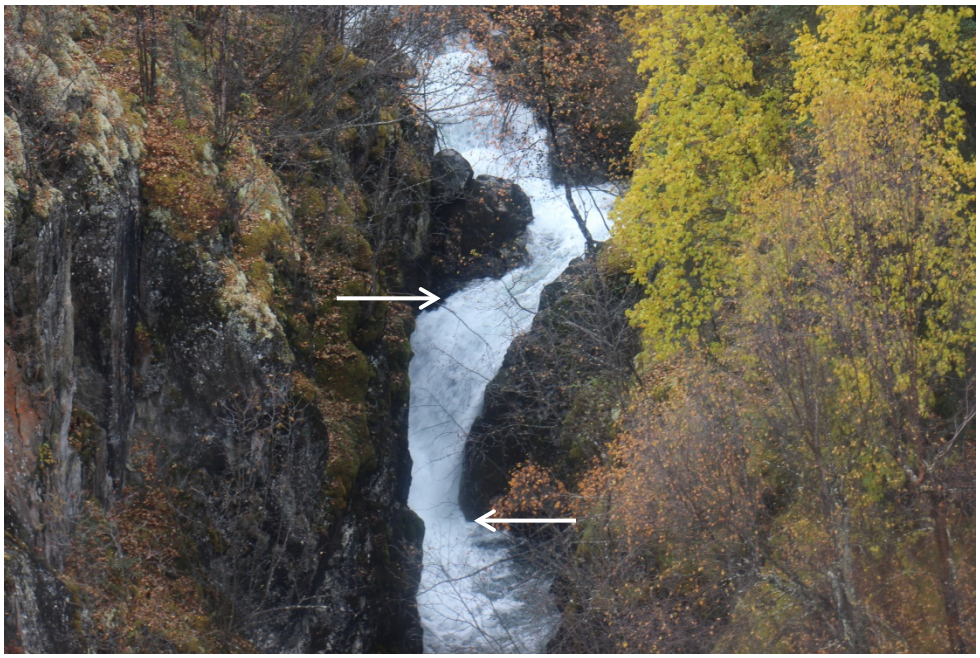

Figure A3. Barrier A in Unnamed Tributary 204.3. Fixed single fall, 10.8 ft in height.

4. BARRIER FIELD NOTES: UNNAMED TRIBUTARY 204.3, BARRIER B

The potential barrier site was located upstream of Barrier A in Unnamed Tributary 204.3 amid a moderate to high gradient reach of stream dominated by boulder cascades. The site was classified as a fixed permanent single falls. The stream turbulence made it difficult to ascertain the bed material upstream and downstream of the feature, but the falls themselves were formed by an exposed bedrock sill (Figure A4).

As a single fall, and due to its location, only the height of the barrier was assessed. The average barrier height was 7.7 ft (2.3 m). A plunge pool existed below the feature. The pool appeared to be highly turbulent, with resting areas likely around the extreme periphery and possibly at depth. Exact depth could not be determined. A steep chute was located immediately upstream of the feature, allowing for difficult landing conditions. Another smaller cascade was located above this chute.

Figure A4. Barrier B in Unnamed Tributary 204.3. Fixed single fall, 7.7 ft in height.

5. BARRIER FIELD NOTES: UNNAMED TRIBUTARY 215.2, BARRIER A

This barrier was surveyed by foot on September 12, 2013 and was located on a tributary entering the Susitna River on river left (Barrier ISR Figure 4.3-1a). The barrier was classified as a complex chute and turbulent cascade with an overall 29.7 m (97.4 ft) vertical drop over a horizontal distance of 177.8 m (583.3 ft). The gradient range was 10 to 15 percent for the bottom half of the falls, increasing to between 20 and 34 percent for the final 18 m (59 ft) vertical drop, with an overall slope of 17 percent. The combination of waterfalls and steep, turbulent, high-velocity chutes with limited resting areas or deep plunge pools confirmed this as a permanent fixed barrier for fish movement (Figure A5).

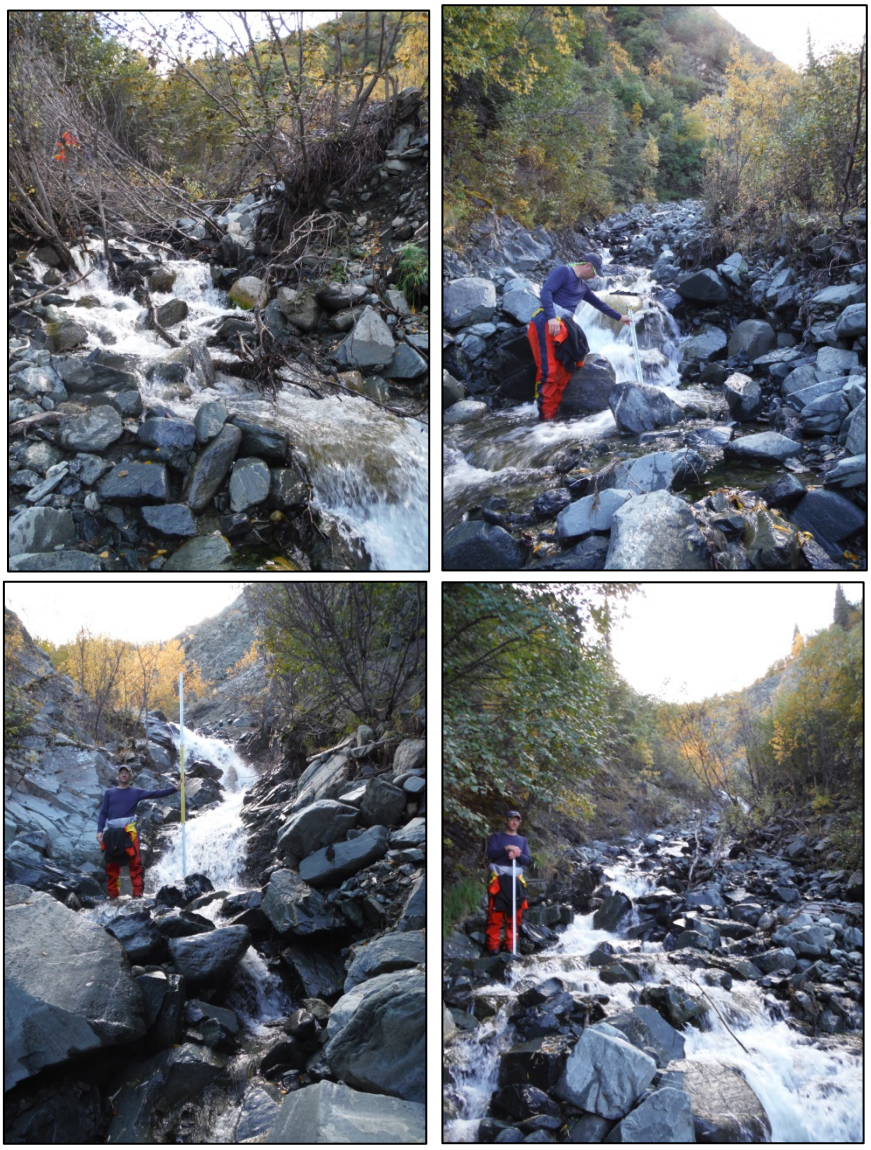

Figure A5. Barrier A in Unnamed Tributary 215.2. Clockwise from top left, views from bottom to top of a complex chute which spans 97 ft in vertical direction and 583 ft in horizontal direction. This is a permanent barrier to fish passage.

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries (9.12)

Part A - Appendix B

Middle River Tributary Delta Surveys Outside of Focus Areas

Initial Study Report

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1. CHASE CREEK

The mouth of Chase Creek was unique compared to the other tributaries surveyed. Although characterized by exposed boulders and cobbles, it did not resemble the large, bedload-deposited aprons seen elsewhere (Figure B1). The mouth exhibited a steepened slope due to the receding Susitna, but no defined channel had been formed in the exposed substrate (Figure B2). The creek flow was spread out across the exposed substrate with no clearly defined or continuous thalweg. A natural and irregular small boulder and cobble weir formed at the top of the mouth grade break, dispersing flow leaving the upstream pool (Table B1). It was likely that the low-gradient nature of this creek had limited the material deposited at the mouth, and that creek flows have not regularly carried enough energy to alter the geometry of the existing debris apron.

Figure B1. Chase Creek. From upper right: bottom of creek mouth; top of creek mouth; low gradient channel resulted in slow meandering reaches; and near top of creek survey.

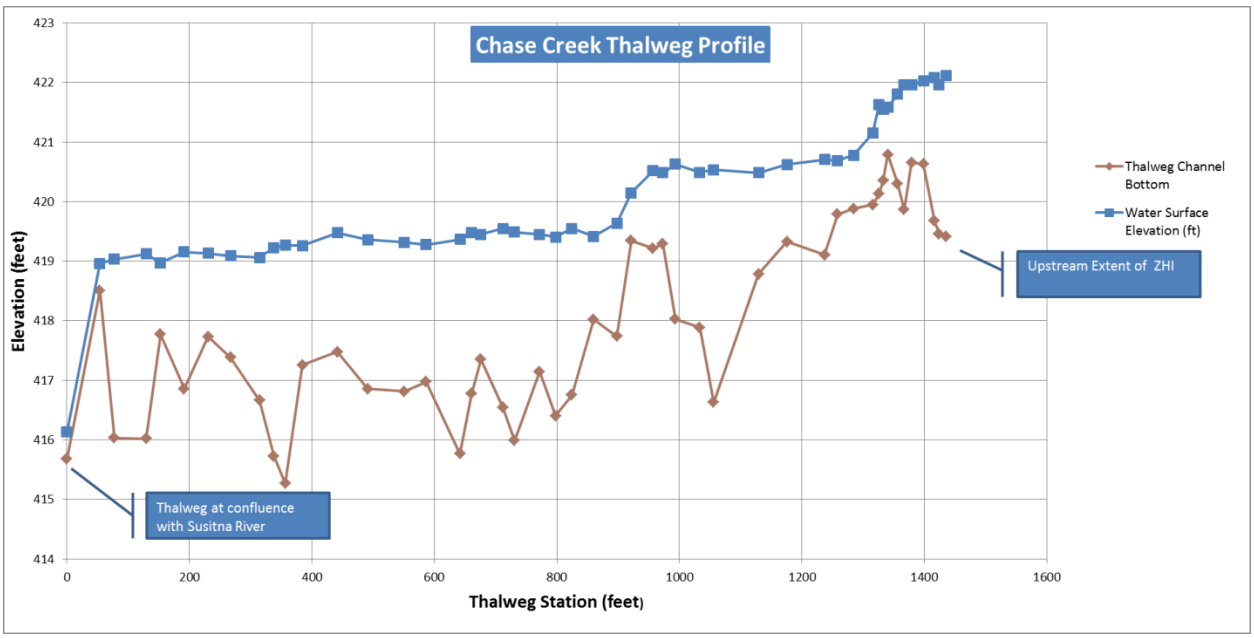

Figure B2. Chase Creek thalweg profile.

Table B1. Chase Creek thalweg station characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	0.45	1.165	5.3	53.8	0	10	80	10	0	0
53.8	0.45	0.476	-10.6	23.4	0	10	70	10	10	0
77.2	3	0.673	0.0	52.5	0	30	30	0	30	0
129.7	3.1	0.636	7.6	23	0	70	30	0	0	0
152.7	1.2	0.713	-2.4	38.8	NRD	10	80	10	0	0
191.5	2.3	0.484	2.2	39.4	0	0	70	30	0	0
230.9	1.4	0.669	-1.0	36.4	0	40	40	10	0	10
267.3	1.7	0.573	-1.5	47.3	0	30	60	0	0	10
314.6	2.4	0.513	-4.0	23.4	0	0	0	10	50	40
338	3.5	0.65	-2.5	18.6	0	0	10	0	10	80
356.6	4	0.185	7.1	28.2	0	0	10	0	40	50
384.8	2	1.397	0.4	57	0	0	0	30	30	40
441.8	2	0.652	-1.2	49.6	0	0	0	0	40	60
491.4	2.5	0.24	-0.1	59.7	0	0	0	20	40	40
551.1	2.5	0.522	0.5	35.1	0	0	0	0	50	50
586.2	2.3	0.468	-2.2	55.4	0	0	0	0	70	30
641.6	3.6	0.336	5.3	19.1	0	0	0	0	50	50
660.7	2.7	0.664	3.7	15.3	0	0	70	0	10	20
676	2.1	0.518	-2.2	35.9	0	0	70	0	10	20
711.9	3	0.634	-3.0	18.7	0	10	10	30	20	30
730.6	3.5	0.773	2.8	41	0	0	0	20	50	40
771.6	2.3	0.618	-2.8	26.3	0	0	0	0	60	40
797.9	3	0.795	1.3	26.5	0	0	10	0	50	40
824.4	2.8	0.481	3.6	35.7	0	0	20	0	40	40
860.1	1.4	1.163	-0.7	38	0	20	60	20	0	0
898.1	1.9	1.601	7.0	22.9	0	30	50	20	0	0
921	0.8	1.855	-0.4	35.9	0	40	50	10	0	0
956.9	1.3	0.958	0.4	15.8	0	40	50	10	0	0
972.7	1.2	1.261	-6.1	20.8	0	40	50	10	0	0
993.5	2.6	0.173	-0.3	39.5	0	50	20	0	20	10
1033	2.6	0.637	-5.5	23	0	0	0	0	50	50
1056	3.9	0.538	2.9	73.3	0	0	0	0	50	50
1129.3	1.7	0.543	1.2	46.3	0	10	80	10	0	0
1175.6	1.3	0.864	-0.4	61.8	0	50	30	10	10	0
1237.4	1.6	0.736	3.3	20.5	0	0	50	40	0	10
1257.9	0.9	1.359	0.3	26.4	0	30	30	30	0	10
1284.3	0.9	2.584	0.2	31.4	0	10	70	20	0	0
1315.7	1.2	2.668	1.8	10.1	0	20	70	10	0	0
1325.8	1.5	1.383	3.2	7.2	0	20	70	10	0	0
1333	1.2	2.218	5.6	7.7	0	20	70	10	0	0
1340.7	0.8	1.421	-3.1	15.5	0	20	50	30	0	0
1356.2	1.5	0.272	-4.0	10.9	0	10	70	20	0	0
1367.1	2.1	0.442	6.5	12.3	0	0	70	30	0	0
1379.4	1.3	0.711	-0.2	19.1	0	40	20	40	0	0
1398.5	1.4	1.326	-5.3	17.8	0	10	70	20	0	0
1416.3	2.4	0.67	-2.7	7.9	0	0	50	40	0	0
1424.2	2.5	0.726	-0.4	11.5	0	0	50	40	0	0
1435.7	2.7	1.224	-	-	0	0	50	40	0	0

2. LANE CREEK

Lane Creek left a very confined and established channel only a short distance upstream of the creek mouth (Figure B3). During high Susitna flow conditions, it was likely that the creek met the river at the end of the confined channel reach (Figure B4). The creek mouth was characterized by large cobbles and small boulders with a debris apron (Table B2). Flows began to spread out across this small boulder apron as it passed the downstream extent of the confining creek bank before reaching the Susitna. No noticeable incision had occurred across the apron, and there was no distinct thalweg.

Figure B3. Lane Creek. From upper right: bottom of creek mouth; top of creek mouth; looking downstream to creek mouth; and looking upstream to top of survey- note uniform channel form.

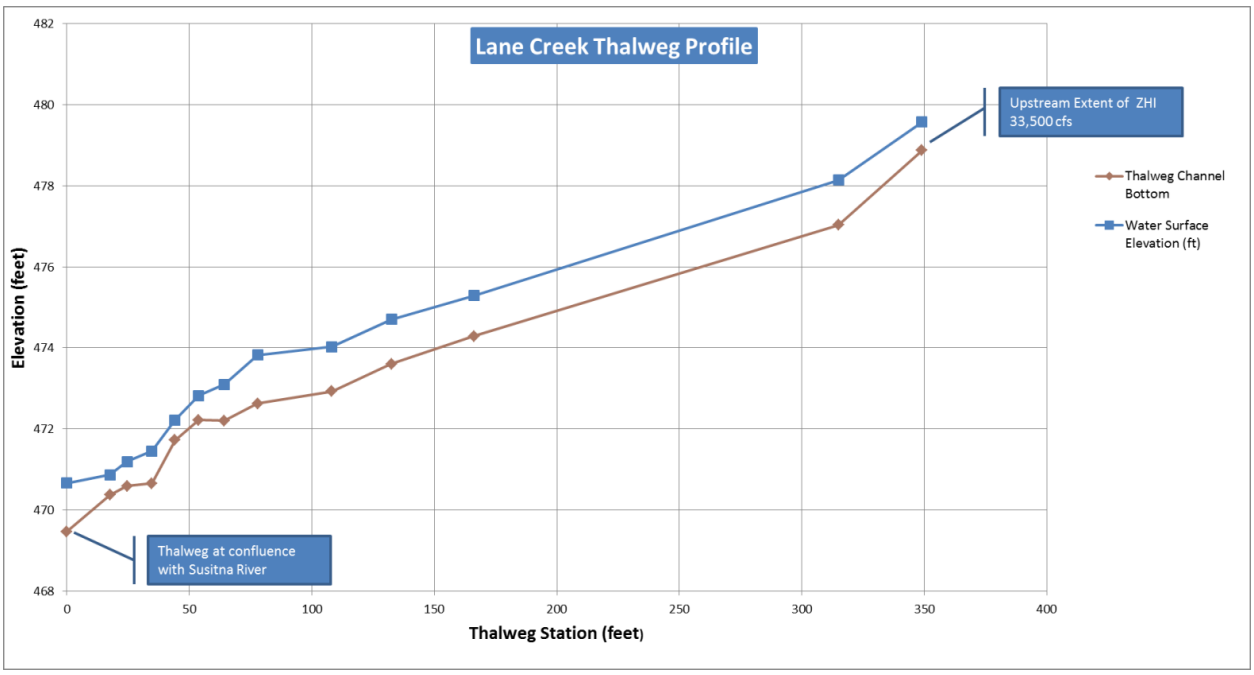

Figure B4. Lane Creek thalweg profile.

Table B2. Lane Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	1.2	2.15	5.2	17.5	0.0	30.0	70.0	0.0	0.0	0.0
17.5	0.5	-0.06	0.9	7	0.0	30.0	50.0	20.0	0.0	0.0
24.5	0.6	1.16	0.2	10.2	0.0	20.0	60.0	20.0	0.0	0.0
34.7	0.8	3.18	2.4	9.4	0.0	30.0	70.0	0.0	0.0	0.0
44.1	0.5	3.06	0.9	9.6	0.0	30.0	50.0	20.0	0.0	0.0
53.7	0.6	1.65	0.0	10.5	0.0	50.0	50.0	0.0	0.0	0.0
64.2	0.9	2.91	0.5	13.6	0.0	40.0	40.0	20.0	0.0	0.0
77.8	1.2	2.72	0.3	30.3	0.0	30.0	40.0	30.0	0.0	0.0
108.1	1.1	0.12	0.5	24.4	0.0	30.0	40.0	30.0	0.0	0.0
132.5	1.1	3.48	0.4	33.6	0.0	10.0	70.0	20.0	0.0	0.0
166.1	1	3.76	0.9	148.9	0.0	10.0	80.0	10.0	0.0	0.0
315	1.1	3.43	0.5	34	0.0	10.0	80.0	10.0	0.0	0.0
349	0.7	3.37	-	-	0.0	50.0	40.0	10.0	0.0	0.0

3. DEADHORSE CREEK

The mouth of Deadhorse Creek consisted of a large debris fan and single creek channel (Figure B5). The creek had incised the debris apron, but a final steep boulder cascade remained before reaching the Susitna (Figure B6). This noticeable perch was a result of low creek flows and the receding Susitna flow. Deposited material varied in gradation, material size and mixture throughout the fan (Table B3).

Figure B5. Deadhorse Creek. From upper right: bottom of creek mouth; looking upstream from Susitna from creek mouth; upstream extent of channel survey; and looking downstream – note channel incision through deposited apron material.

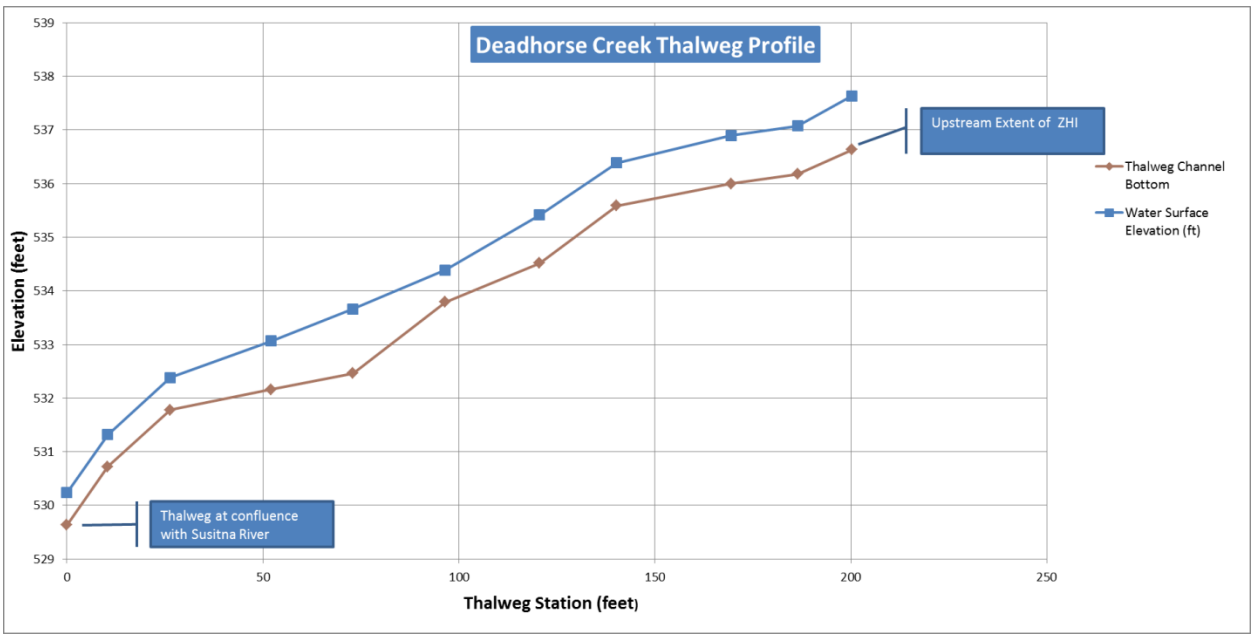

Figure B6. Deadhorse Creek thalweg profile.

Table B3. Deadhorse Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	0.6	4.189	10.5	10.4	0	50	50	0	0	0
10.4	0.6	1.253	6.6	16	0	30	50	20	0	0
26.4	0.6	2.764	1.5	25.7	0	30	50	20	0	0
52.1	0.9	3.347	1.4	20.9	0	30	50	20	0	0
73	1.2	1.811	5.6	23.5	0	30	50	20	0	0
96.5	0.6	2.986	3.0	24.1	0	0	60	40	0	0
120.6	0.9	2.782	5.4	19.6	0	0	80	20	0	0
140.2	0.8	1.72	1.4	29.3	0	40	40	20	0	0
169.5	0.9	1.722	1.1	16.9	0	50	30	20	0	0
186.4	0.9	0.173	3.3	13.9	0	50	30	20	0	0
200.3	1	2.281	-	-	0	40	40	20	0	0

4. FIFTH OF JULY CREEK

The mouth of Fifth of July Creek was perched due to the receding Susitna and large amounts of mixed sediment were deposited (Figure B7). A haphazard orientation and mixture of the debris indicated that high creek flows had mobilized all sizes of material, and deposited it abruptly upon reaching the slower waters of the Susitna (Table B4). The stream was incised through the deposited material with consistent channel shape, thereby reducing the magnitude of the perch (Figure B8).

Figure B7. Fifth of July Creek. From upper right: bottom of creek mouth; looking upstream from Susitna from creek mouth; apron deposits – mixed fines to boulders; and looking downstream from top of survey.

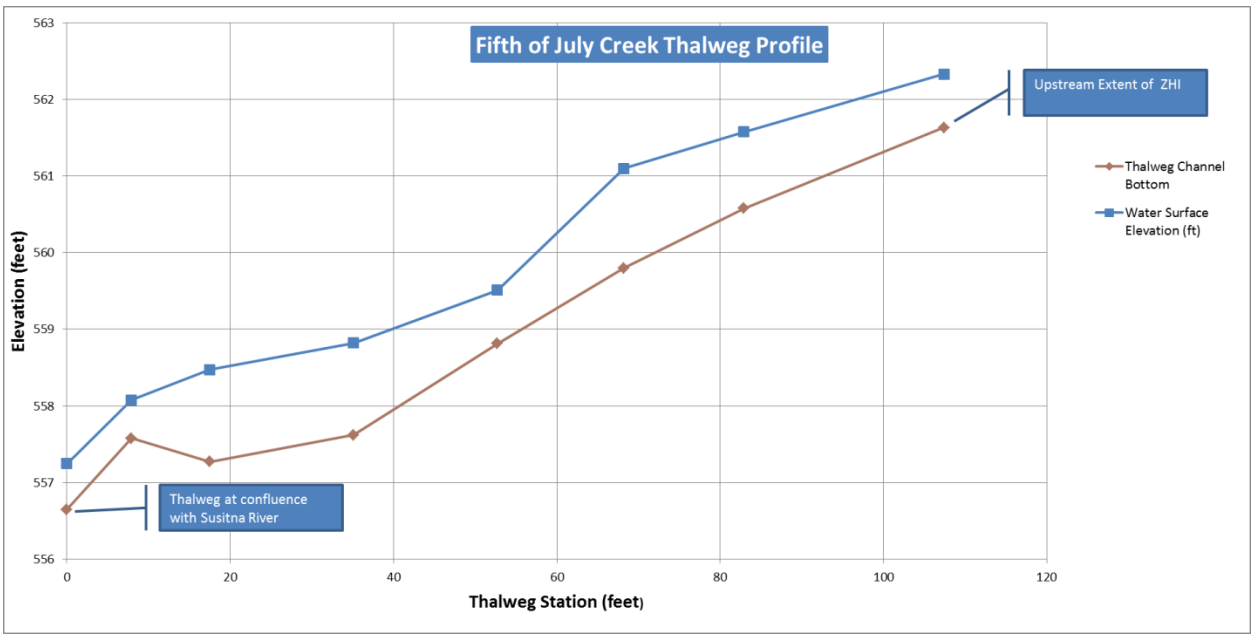

Figure B8. Fifth of July Creek thalweg profile.

Table B4. Fifth of July Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	0.6	2.95	11.8	7.9	0	30	40	30	0	0
7.9	0.5	3.44	-3.2	9.6	0	20	40	40	0	0
17.5	1.2	2.19	2.0	17.6	0	30	40	30	0	0
35.1	1.2	2.11	6.8	17.6	0	40	30	30	0	0
52.7	0.7	2.73	6.4	15.5	0	40	30	30	0	0
68.2	1.3	1.90	5.3	14.7	0	50	30	20	0	0
82.9	1	4.71	4.3	24.5	0	50	30	20	0	0
107.4	0.7	2.01	-	-	0	0	60	40	0	0

5. FOURTH OF JULY CREEK

The lower channel of Fourth of July Creek flowed parallel to the Susitna, and was divided by a large gravel/cobble bar (Figure B9). As the creek approached its mouth, flow split into side channels before reaching the Susitna. Five or six significant channels, which varied in slope, length, and discharge, flowed from the creek over a distance of approximately 50 m (164 ft). The main channel carried approximately 25 percent of the creek flow to the Susitna. Some of the channels were actively eroding during the survey. While the mouth was still perched during the time of survey, the length of the multiple channels and the general geometry of the gravel/cobble bar did not create an abrupt drop as seen on several other creeks (Figure B10, Table B5).

Figure B9. Fourth of July Creek. From upper right: bottom of creek mouth; multiple channels through creek mouth; channel upstream of mouth – flowing parallel to the Susitna; and upstream confluence of channel split near top of survey.

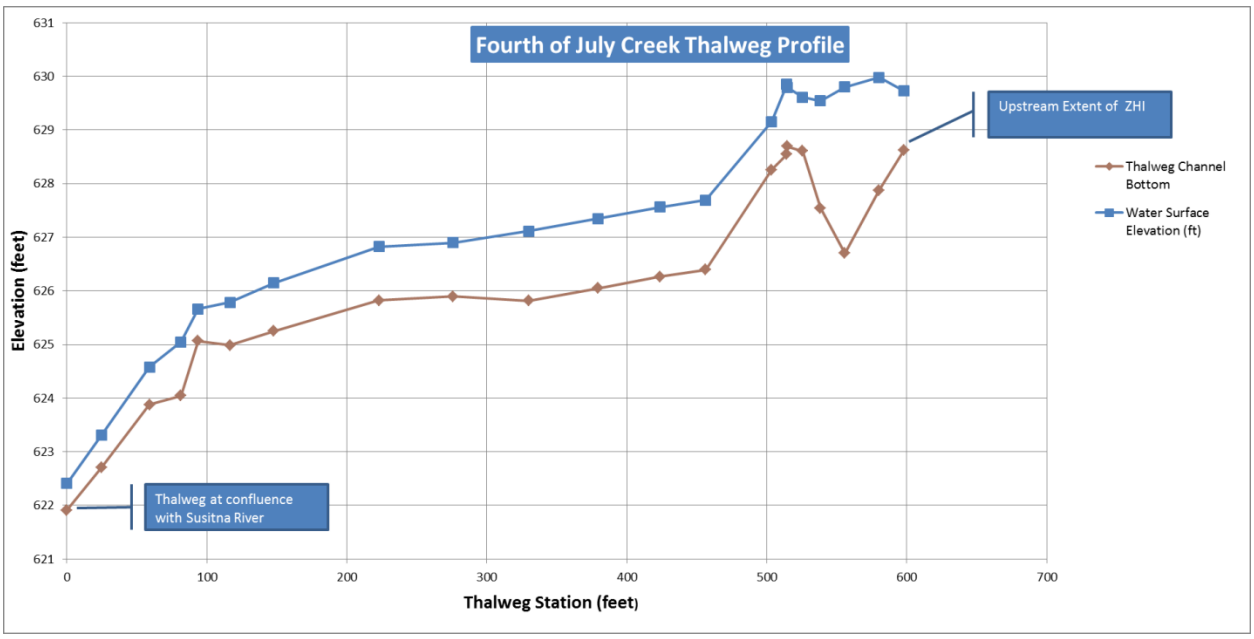

Figure B10. Fourth of July Creek thalweg profile.

Table B5. Fourth of July Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	0.5	4.946	3.2	24.6	0	0	20	80	0	0
24.6	0.6	3.771	3.4	34.4	0	0	30	70	0	0
59	0.7	4.145	0.7	22.4	0	0	30	70	0	0
81.4	1	4.746	8.4	12.2	0	0	40	60	0	0
93.6	0.6	2.542	-0.3	22.8	0	0	10	80	10	0
116.4	0.8	3.133	0.8	31.3	0	0	30	70	0	0
147.7	0.9	2.459	0.8	75.1	0	0	40	60	0	0
222.8	1	1.696	0.1	53.1	0	0	40	40	20	0
275.9	1	2.026	-0.2	53.8	0	0	40	40	20	0
329.7	1.3	1.815	0.5	49.7	0	0	70	30	0	0
379.4	1.3	3.059	0.5	44.3	0	0	20	70	10	NRD
423.7	1.3	3.743	0.4	32.5	0	0	20	70	10	0
456.2	1.3	4.246	4.0	47.1	0	10	80	10	0	0
503.3	0.9	3.047	2.7	10.9	0	0	80	20	0	0
514.2	1.3	2.85	48.1	0.3	0	10	50	30	10	0
514.5	1.1	1.85	-0.8	10.9	0	0	50	30	20	0
525.4	1	1.385	-8.4	12.7	NRD	0	50	30	20	0
538.1	2	0.946	-4.8	17.5	0	0	50	30	20	0
555.6	3.1	0.936	4.8	24.4	0	0	30	30	40	0
580	2.1	2.554	4.2	17.9	0	10	60	30	0	0
597.9	1.1	4.426	-	-	0	10	40	20	0	30

6. SHERMAN CREEK

The mouth of Sherman Creek extended across a short debris fan (Figure B11). The stream crossed in a single channel, and upon reaching the perched edge of the fan, flow divided between a few main flow paths before reaching the Susitna (Figure B12, Table B6).

Figure B11. Sherman Creek. From upper right: bottom of creek mouth; multiple channels through creek mouth; riffle upstream of tributary apron; and looking downstream from top of survey.

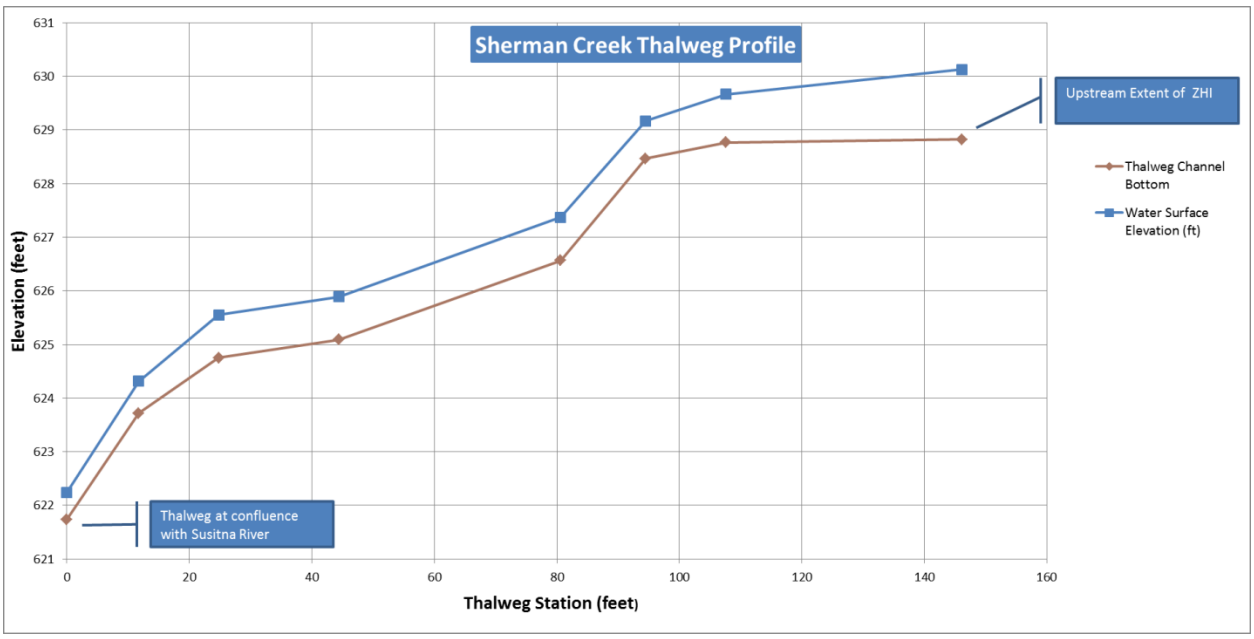

Figure B12. Sherman Creek thalweg profile.

Table B6. Sherman Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	0.5	5.948	16.9	11.7	0	20	50	30	0	0
11.7	0.6	2.117	7.9	13.1	0	20	50	30	0	0
24.8	0.8	2.785	1.7	19.6	0	50	30	20	0	0
44.4	0.8	3.592	4.1	36.2	0	60	30	10	0	0
80.6	0.8	3.837	13.7	13.9	0	80	20	0	0	0
94.5	0.7	2.831	2.3	13.1	0	20	60	20	0	0
107.6	0.9	0.597	0.2	38.5	0	20	60	20	0	0
146.1	1.3	0.981	-	-	0	30	50	20	0	0

7. GOLD CREEK

The mouth of Gold Creek consisted of a large debris fan and two stream channels (Figure B13). A steeper channel grade across the deposited apron was consistent with a perched condition, but channel incision on both the main and the secondary channel reduced the gradient of the final drop to the Susitna (Figure B14, Table B6). Flow between the two flow paths consisted of an approximate 60:40 split. Banks of the secondary channel were eroding during the time of survey.

Figure B13. Gold Creek. From upper right: bottom of creek mouth; bottom of mouth side channel; lower gradient reach upstream of tributary apron; and higher gradient reach near top of survey.

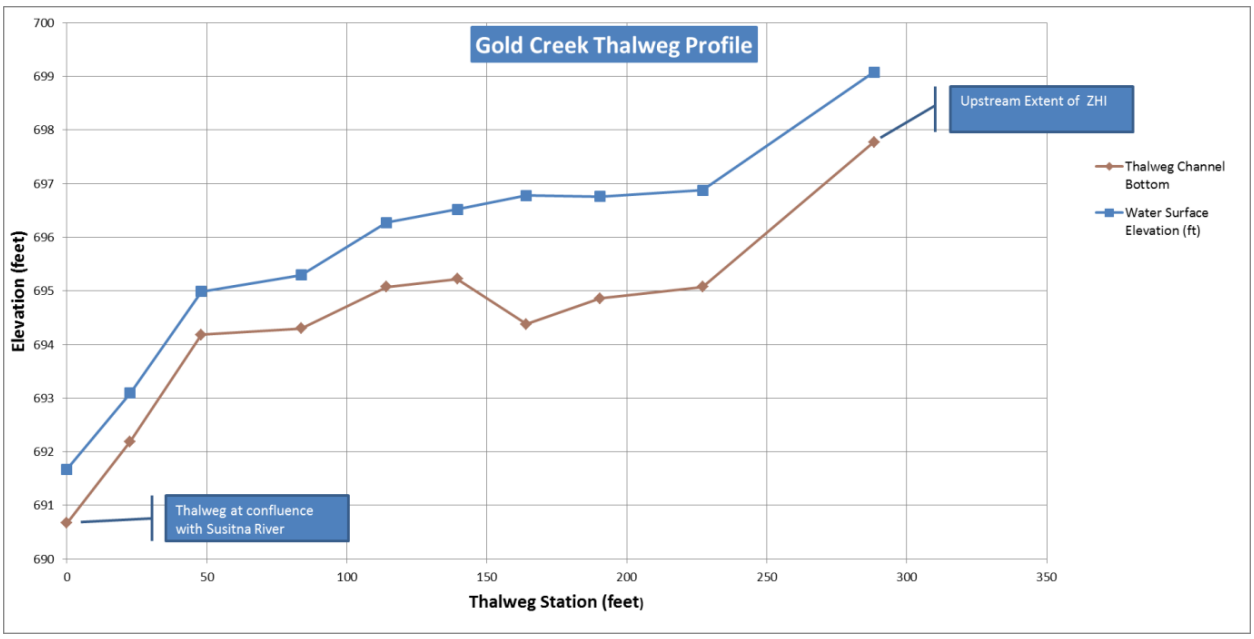

Figure B14. Gold Creek thalweg profile.

Table B6. Gold Creek thalweg characteristics.

Thalweg Station (ft)	Flow Depth (ft)	Localized Velocity (ft/sec)	Upstream Channel Gradient (%)	Upstream Reach Length (ft)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0	1	5.08	6.7	22.6	0	30	70	0	0	0
22.6	0.9	3.45	7.8	25.4	0	30	70	0	0	0
48	0.8	2.08	0.3	35.6	0	30	50	20	0	0
83.6	1	4.80	2.5	30.6	0	10	90	0	0	0
114.2	1.2	2.09	0.6	25.3	0	10	80	10	0	0
139.5	1.3	2.12	-3.4	24.6	0	40	40	20	0	0
164.1	2.4	3.91	1.8	26.3	0	30	50	20	0	0
190.4	1.9	3.44	0.6	36.7	0	30	50	20	0	0
227.1	1.8	2.87	4.4	61.2	0	40	40	20	0	0
288.3	1.3	4.42	-	-	0	50	50	0	0	0